ENVIRONMENT PROTECTION, CHEMICAL AND BIOTECHNOLOGY

UDC: 502.175:[502.3:613.15(045)
DOI 10.18372/2306-1472.80.14275

Volodymyr Isaenko[1]
Artur Zaporozhets[2]
Katerina Babikova[3]
Dmytro Gulevets[4]
Serhii Savchenko[5]

REVIEW OF METHODS AND MEANS OF MONITORING THE AIR POLLUTION

[1,3,4,5]National Aviation University,1, Lubomyr Husar ave., 03058, Kyiv, Ukraine
[2] Institute of Engineering Thermophysics of NAS of Ukraine
Akademika Bulakhovs'koho St, 2-4, 02000, Kyiv, Ukraine
E-mails: [1]volodymyr.isaienko@gmail.com, [2]a.o.zaporozhets@nas.gov.ua, [3]babikova.kateryna@gmail.com, [4]gulevets@gmail.com, [5]serj6670@gmail.com

Abstract

The article analyzes the current state of methods and means of monitoring air pollution in Ukraine. The issues of the formation of pollutants during the combustion of various types of fuel (gaseous, liquid, solid) in large power plants are considered. The data about the largest sources of air pollution in Ukraine are given. The main disadvantages of the model of the spread of pollutants in the air, which is used as a base, are reflected. The current state of air pollution monitoring systems, both in Ukraine and in other countries, is investigated. The improvement of the existing air pollution monitoring system based on unmanned aerial vehicles is proposed.

Keywords: air pollution; monitoring; control; AQI; unmanned aerial vehicles; heat engineering

1. Formulation of the problem

The rational use of nature involves the management of natural processes, that is, the programmed influence on natural objects in order to obtain the necessary economic effect. In order for management to be effective enough, it is necessary to have data on the dynamic properties of these objects, their change as a result of anthropogenic impact, to anticipate the consequences of human intervention in the course of natural processes.

So the current state of environmental problems cannot be considered satisfactory. Problems of environmental research have a large number of directions, each of which is characterized by a specificity [1,2]. The largest development in Ukraine has been the direction of environmental research of energy objects, primarily municipal and industrial heat power. Within this area, state programs have been formed, and relevant and important studies have been conducted [3,4].

The current state of the technical equipment of the thermal power facilities, which have largely exhausted their resources, requires the creation of new monitoring systems for the remote control of air around these facilities. This is caused both by the need to directly control the state of functioning of the heat generating objects (modes of combustion of fuel directly affect the composition of combustion products), and by predicting the spread of harmful substances in different layers of the atmosphere, which are formed during their functioning.

Conducting related research requires the use of modern science and technology, the latest information and measurement systems, and their effectiveness depends on the level of development and practical use of hardware and software measuring systems.

2. Analysis of literary sources and problem statement

Industrial and municipal heat power facilities (TPPs, boiler houses, etc.) belong to the circle of critical and potentially dangerous facilities. Implementation of international and state programs to protect the environment and especially the environment in areas where potentially ecologically hazardous enterprises are located, including energy facilities, requires constant monitoring of the environment [4,5]. In addition, the organization of such monitoring is an important link in the list of measures to support the energy security of Ukraine [4,6].

In [7–10], systems built on the basis of stationary ground control points were considered. Their location is carried out taking into account the environmental features of the terrain, landscape type, meteorological conditions, characteristics of the sources of potential threats in conjunction with economic and physical-technical factors. The development and operation of such systems is not always justified for several reasons. Among them: the impossibility of determining the level of air pollution at different heights from the source of pollution, limited data, insufficient number of measurement points to determine dangerous concentration fields and obtaining information about the level of pollution, insufficient response rate of stationary systems in case of emergency.

Thus, the problem of developing a monitoring complex for the state of environmental air pollution based on the use of unmanned aerial systems is currently relevant in the power system.

3. Purpose and research's objectives

The studies were aimed at establishing approaches to the development of a monitoring complex for the state of environmental air pollution, including on the basis of unmanned aerial systems (UAS) with determination of the spatial concentration fields of harmful substances in various layers of the atmosphere.

For achieving the goal, the following tasks were set:

- to analyze the pollutants generated during the operation of heat power objects, and to explore the possibilities of their detection;
- explore approaches to calculating the spread of harmful substances in the air from point sources of pollution;
- to consider the features of the functioning of automated air pollution control systems and explore their distribution in the world;
- to develop an approach for monitoring the state of environmental air on the basis of UAS.

4. Harmful substances in fuel combustion products

The type of fuel affects the composition of the harmful substances that form after combustion. Power plants use solid, liquid and gaseous fuels. The main harmful substances contained in the boiler's exhaust gas are: sulfur oxides (SO_2 and SO_3), nitrogen oxides (NO and NO_2), carbon monoxide (CO), vanadium compounds (mainly vanadium pentaxide V_2O_5). Ash is also a harmful pollutant.

Coal (brown, stone, anthracite), oil shale, and peat belong to the solid fuel used in the power system. The schematic composition of solid fuel is shown in Fig. 1.

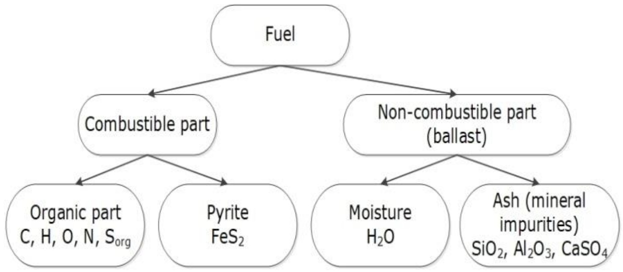


Fig. 1. Solid fuel composition

As can be seen from Fig. 1, the organic part of the fuel consists of carbon C, hydrogen H_2, oxygen O_2, organic sulfur S. The mineral part of the fuel consists of moisture W and ash A. The main part of the mineral component of the fuel goes into fly ash during combustion.

Liquid fuels used in the power system include fuel oil, shale oil, diesel and boiler fuel. Pyrite sulfur is absent in liquid fuel. Fuel oil ash contains V_2O_5, Ni_2O_3, Al_2O_3, Fe_2O_3, SiO_2, MgO and oxides.

The ash content of fuel oil does not exceed 0.3%. During fully combustion, the solid content in the exhaust gas is about 0.1 g/m^3.

Sulfur in fuel oil is found mainly in the form of organic compounds, "pure" sulfur and hydrogen sulfide. Its content depends on the sulfur content of the oil from which it is made.

Diesel fuel by sulfur content is usually divided into 2 groups: 1 – up to 0.2% and 2 – up to 0.5%. In low-sulfur boiler-furnace fuel, the sulfur content does not exceed 0.5%, in sulfur – up to 1.1; in shale oil – not more than 1%.

Gaseous fuels are the most "clean" fossil fuels, and only nitrogen oxides and carbon monoxide CO can be formed during its combustion (in case of incomplete combustion). Details on the mechanisms of formation of chemical under burning products during the combustion of natural gas are given in [11-12].

Harmful emissions and natural substances in the atmosphere undergo complex transformation processes: transformation, interaction, leaching, etc.

These processes are different for solid and gaseous impurities. The following factors have a significant impact on the process of dispersion in the atmosphere of emissions coming from chimneys and ventilation devices:

- state of the atmosphere;
- physical and chemical properties of substances that make up the emissions (density, gas temperature, dispersed dust composition, etc.);
- height and diameter of the source of emission;
- location of emission sources;
- terrain.

A schematic distribution of the concentration of pollutants in the atmosphere under the torch of a high point source is shown in Fig. 2.

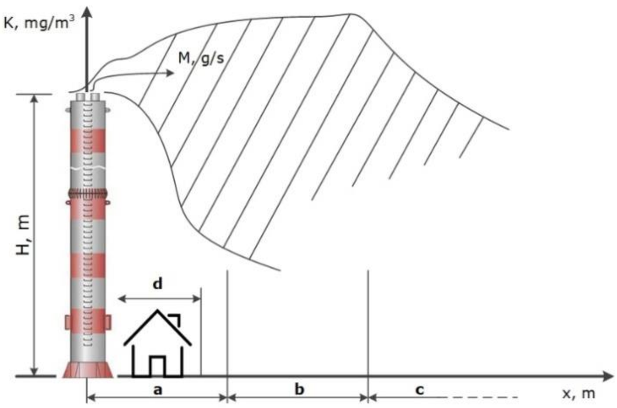


Fig. 2. Schematic change in the distribution of pollutants in the atmosphere under a point source flare: *a* – flare tipping zone; *b* – smoke zone; *c* – zone with reducing pollution; *d* – fugitive emission zone

Inside the flare transfer zone, high concentrations of substances occur due to fugitive emissions. The smoke zone is the most dangerous, its dimensions, depending on weather conditions, are within 10-50 heights of the chimney.

The maximum concentration of pollutant K in the surface layer of the atmosphere is directly proportional to the mass flow rate of the pollutant M and inversely proportional to the square of the height of the source H^2.

The high concentration of various pollutants in the air negatively affects the whole complex of wildlife. The negative impact of harmful impurities in the atmosphere is in the deterioration of the people's and animals' health, reducing the yield of crops. Atmospheric pollution also affects the corrosion processes of building structures, the acceleration of wear of buildings and equipment.

Not only harmful emissions from thermal power plants, but also from other industrial enterprises, transport, and utilities get into the atmosphere. Table 1 shows the distribution of emissions of harmful substances into the atmosphere from objects of various industries [13].

As can be seen from the above data, in the pollution of atmospheric air, the main role is played by the objects of the thermal power, metallurgical and transport industries. Their total contribution to environmental pollution is about 2/3 of the total harmful emissions from industry.

Table 1

Ratio of harmful substances' emissions into the atmosphere between industries

Objects and industries	Share of harmful emissions into the atmosphere, %
TPPs and boiler rooms	27
Ferrous metallurgy	17
Oil production and petrochemistry	16
Automobile transport	12
Non-ferrous metallurgy	10
Construction industry	5
Coal industry	2,5
Chemical industry	1,5
Other industries	9
Total:	**100**

The amount of permissible concentration of harmful substances for humans in the environment is determined on the basis of 2 MPC indicators (maximum permissible concentration): maximum one-time ($MPC_{m.o.t.}$) and daily average ($MPC_{a.v.}$) at the level of respiration.

MPC of harmful substances produced by the objects of the heat and power industry are presented in Table 2.

Table 2

MPC values for some substances at the level of human respiration

Substance	Formula	$MPC_{m.o.t.}$	$MPC_{a.v.}$
Nitrogen dioxide	NO_2	0.085	0.04
Nitrogen oxide	NO	0.6	0.06
Sulfur dioxide	SO_2	0.5	0.05
Benzapyrene	$C_{20}H_{16}$	—	10^{-6}
Vanadium Pentaxide	V_2O_5	—	0.002

End Table 2

Substance	Formula	MPCm.o.t.	MPCa.v.
Carbon monoxide	CO	5	3
Ammonia	NH_3	0.2	0.04
Hydrogen sulfide	H_2S	0.008	—
Soot	—	0.15	0.05
Inorganic dust containing silicon dioxide,%			
>70	—	0.15	0.05
20–70	—	0.3	0.1
<20	—	0.5	0.15
Coal ash of TPP	—	0.05	0.02

5. Emission distribution modeling

The methods for predicting atmospheric air pollution are based on the results of theoretical and experimental studies of the patterns of distribution of impurities produced by sources of air pollution [14-15].

Analysis of the spread of harmful impurities is based on the development of a theory of atmospheric diffusion based on a mathematical description of the process using the equation of turbulent diffusion. It allows studies of the propagation of impurities from sources of various types and with different environmental characteristics.

In general terms, the task of predicting environmental air pollution can be defined as a solution under certain initial and boundary conditions of the differential equation (1):

$$\sum_{i=1}^{3} V_i \frac{\partial K}{\partial x_i} + \frac{\partial K}{\partial t} = \sum_{i=1}^{3} \frac{\partial}{\partial x_i} C_i \frac{\partial K}{\partial x_i} - aK, \quad (1)$$

where V_i is the average velocity of the impurity; K is the impurity concentration; x is the coordinate; t is the propagation time of the impurity; C_i are the components of the exchange coefficient; a is a coefficient that determines the change in concentration due to the transformation of the impurity.

In the Cartesian coordinate system, the equation takes the form:

$$\frac{\partial K}{\partial t} + V_x \frac{\partial K}{\partial x} + V_y \frac{\partial K}{\partial y} + V_z \frac{\partial K}{\partial z} = \frac{\partial}{\partial x} C_x \frac{\partial K}{\partial x} + \frac{\partial}{\partial y} C_y \frac{\partial K}{\partial y} + \frac{\partial}{\partial z} C_z \frac{\partial K}{\partial z} - aK. \quad (2)$$

During solving practical problems, the form of equation (2) can be simplified. For example, if the x axis is oriented along the direction of the average wind speed, then $V_y = 0$. Moreover, a complete list of permissible simplifications is given in [14].

Thus, equation (2) can be simplified to the form (3):

$$V_x \frac{\partial K}{\partial x} - V_z \frac{\partial K}{\partial z} = \frac{\partial}{\partial y} C_y \frac{\partial K}{\partial y} + \frac{\partial}{\partial z} C_z \frac{\partial K}{\partial z} - aK. \quad (3)$$

In the case of consideration of light impurities, the equation of distribution of the pollutant in the atmosphere takes the form (4):

$$V_x \frac{\partial K}{\partial x} = \frac{\partial}{\partial y} C_y \frac{\partial K}{\partial y} + \frac{\partial}{\partial z} C_z \frac{\partial K}{\partial z} - aK. \quad (4)$$

In the study of impurities that do not transform during the propagation process, equation (3) has the form (5):

$$V_x \frac{\partial K}{\partial x} = \frac{\partial}{\partial y} C_y \frac{\partial K}{\partial y} + \frac{\partial}{\partial z} C_z \frac{\partial K}{\partial z}. \quad (5)$$

Usually, during predicting of air pollution, only the concentration of harmful impurities in the surface layer is determined at a level of $h \leq 2$m. At the level z = h (in the surface layer), the equality $C_z = C_0$ is approximately adopted, where C_0 is the molecular diffusion coefficient for air.

An analytical expression for solving the diffusion equation can be written if V_x and C_z are given by power functions of z ($V_x = V_x^1 \cdot z^n$; $C_z = C_z^1 \cdot z$) for a light impurity that does not transform during propagation. In this case, the solution of equation (1) will have the form (6):

$$K = \frac{M}{2 \cdot (n-1) \cdot C_z^1 \cdot \sqrt{\pi C_0 x^3}} \cdot e^{\frac{V_x^1 H^{1+n}}{(1+n)^2 C_z^1 x} - \frac{y^2}{4 C_0 x}}, \quad (6)$$

where M is the emission from the source per unit time, mg/s; H is the height of the source of emission, m.

The results of a theoretical calculation of the distribution of the concentration of harmful substances from a point source are shown in Fig. 3.

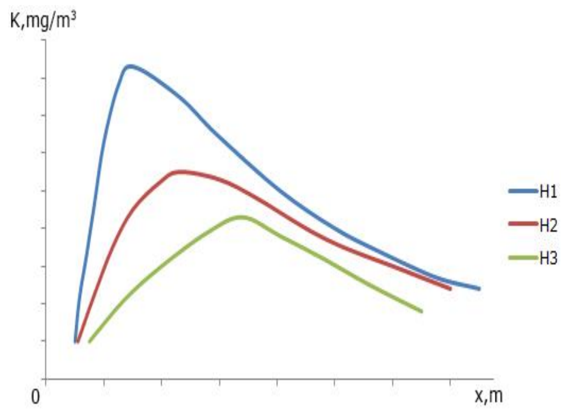


Fig. 3. Theoretical distribution of the concentration of impurities in air K at a distance x from a point source of different heights H: $H1 < H2 < H3$

A characteristic feature of the distribution of ground-based concentration K along the x axis is the presence of a maximum K_m at a distance x_m from the source.

With the same emission parameters, the maximum surface concentration from a higher source is less and is observed at a greater distance from the source.

6. Automated air control systems

In general, monitoring of atmospheric air is monitoring its condition and warning of critical situations that can be harmful / dangerous to human health and other living organisms. The monitoring processes of energy facilities (in particular thermal power plants, boiler houses, etc.) can be illustrated by the structure [16] shown in Fig. 4.

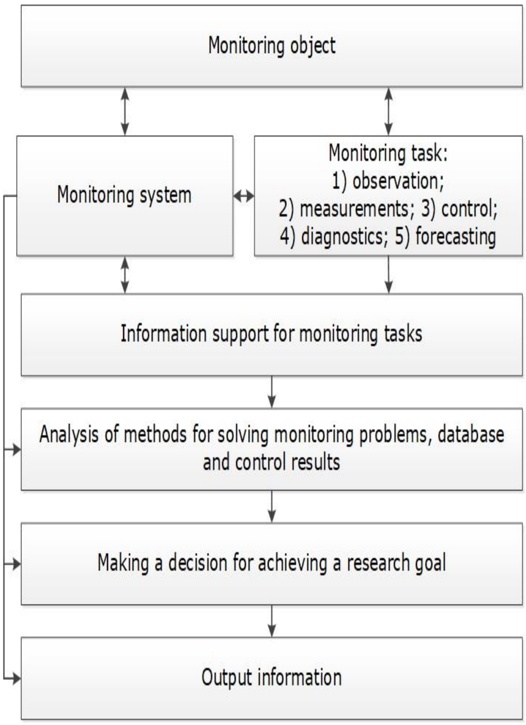


Fig. 4. The structure of the monitoring process of energy facilities

In many industrialized countries and large industrial areas, automated air pollution control systems (AAPCS) operate, which are a network of monitoring and measuring stations equipped with sensors, equipment and communication channels.

Obtained data is sent to the information center, where data about the level of air pollution in controlled areas are collected and processed [14-17].

Tasks that can be solved by AAPCS:

1) automatic monitoring and recording of concentrations of pollutants;

2) analysis of the information received for determining the actual state of air pollution;

3) the adoption of emergency measures for combating with pollution;

4) forecasting the level of pollution;

5) making recommendations for improving the environment;

6) refinement and verification of dispersion's calculations of impurities.

AAPCS are intended for measuring the concentration of one or more substances: CO, NO, NO_2, SO_2, O_3, NH_3, H_2S, CH, CH_4, C_6H_6, $C_6H_5CH_3$, C_6H_5OH, CH_2O, C_8H_8, C_8H_{10}, HNO_2, $C_{10}H_8$, O_2, CO_2, PM10, PM2.5 (suspended solids).

These substances are measured by a number of specific sensors, in particular electrochemical, ampermetric, semiconductor, piezoelectric, photometric sensors using fiber optics and indicator tubes, biosensors, sensors based on surface-active fibers, etc. Together with measuring the concentration of pollutants, humidity, temperature, pressure, direction and wind speed are also carried out. In Fig. 5 presents a map with data coming from AAPCS in real time (according to www.aqicn.org).

Fig. 5. Visualization of the state of environmental pollution based on real-time data received from AAPCS

On the map, the air quality index (AQI) on the earth's surface is shown in color and numerically, the value of which is used to convey information about the level of environmental pollution at present. Most harmful substances are not related to the air quality index.

According to the EPA standard, the following substances can be used to determine the AQI: SO_2, NO_2, CO, O_3, PM2.5, PM10 [18-19].

In the Table 3 shows the ranges of concentrations of pollutants and the corresponding ranges of AQI.

The formula for determining AQI is as follows:

$$I = \frac{I_{\max} - I_{\min}}{C_{\max} - C_{\min}} \cdot (C - C_{\min}) + I_{\min}, \qquad (7)$$

where I is the current value of AQI; I_{max} is the maximum value of AQI for the current concentration range of the pollutant; I_{min} is the minimum AQI value for the current range of the pollutant's concentration; C_{max} is the maximum value of the current concentration range of the pollutant; C_{min} is the minimum value of the current concentration range of the pollutant; C is the current concentration of the pollutant.

Table 3

Ranges of AQI values and air pollutant concentrations

AQI	NO_2 (ppb)	SO_2 (ppb)	CO (ppm)	PM_{10} (мкг/м^3)	$PM_{2,5}$ (мкг/м^3)	O_3 (ppb)
I_{min}–I_{max}	C_{min}–C_{max}	C_{min}–C_{max}	C_{min}–C_{max}	C_{min}–C_{max}	C_{min}–C_{max}	C_{min}–C_{max}
0-50	0-53*	0-35*	0-4.4**	0-54***	0-12***	0-54**
51-100	54-100*	36-75*	4.5-9.4**	55-154***	12.1-35.4***	55-70**
101-150	101-360*	76-185*	9.5-12.4**	155-254***	35.5-55.4***	71-85** 125-164*
151-200	361-649*	186-304*	12.5-15.4**	255-354***	55.5-150.4***	86-105** 165-204*
201-300	650-1249*	305-604***	15.5-30.4**	355-424***	105.5-250,4***	106-200** 205-404*
301-400	1250-1649*	605-804***	30.5-40.4**	425-504***	250.5-350.4***	405-504*
401-500	1650-1049*	805-1004***	40.5-50.4**	505-604***	350.5-500.4***	505-604*

Note: * – the average concentration of the pollutant over 1 hour; ** – the average concentration of the pollutant for 8 hours; *** – the average value of the concentration of the pollutant for 24 hours.

Table 4 shows the hazard level data characterizing each of the corresponding AQI ranges.

As can be seen from Fig. 5, on the territories of Ukraine, Russia, Belarus and other CIS countries there are almost no AAPCS, which can operate according to international standards and produce data about the composition of the ambient air in real time.

The existing network of air pollution monitoring in Ukraine includes posts for manual sampling of air and AAPCS. Observation posts can be stationary, route and mobile.

From the manual sampling stations, samples for analysis are delivered to the chemical laboratory. AAPCS are stationary and equipped with devices for continuous sampling and analysis of air samples and information transfer via wired/wireless communication channels to the control center and control the state of atmospheric air in a given mode.

Table 4

Caution regarding AQI levels

AQI	Designation	Warning
0-50	good	Air quality is satisfactory, air pollution is negligible (in normal limits)
51-100	satisfactory	Air quality is acceptable, but some pollutants can be dangerous for people who are especially sensitive to polluted air
101-150	bad for sensitive groups	An effect on a particularly sensitive group of individuals may be observed. No visible effect on the average resident
151-200	bad	Everyone can feel the consequences for their health. A particularly sensitive group may feel more serious consequences
201-300	very bad	Health hazard from emergency. Probably there will be an effect on the entire population
300+	dangerous	Health hazard, everyone can feel serious consequences for their health

In Ukraine and the CIS countries, a number of AAPCS modifications have been developed that can function according to international standards.

However, to date, it has not been possible to fully organize their mass production and widespread use. Among the reasons that led to this situation:

1) low operational reliability and quality of instruments and gas analysis equipment used;

2) deficit of financial and material resources;

3) lack of the necessary legislative framework, departmental fragmentation.

7. Air pollution monitoring system based on UAS

The monitoring procedure is implemented using various technical means. In automatic mode, it is advisable to carry out such monitoring in the atmosphere, because in many cases the atmosphere is the environment and distribution of various physical fields and radioactive substances that characterize the current state of heat power facilities.

In addition, the collection of measurement information in the air in the vicinity of these objects can be carried out in significant areas (from ones to hundreds kilometers) remotely (without physical contact with the object of observation) in automatic mode and almost continuously in time.

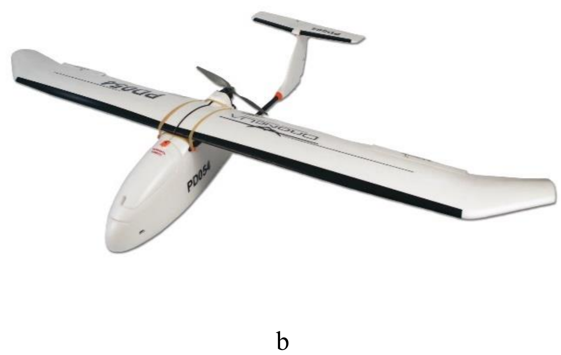
Such control can be carried out not only in regular modes, but also at the initial stages of the development of threats of various kinds and during the liquidation of accidents at energy facilities, which pose a potential threat to human health and life.

Under the conditions of a constantly growing anthropogenic load and an increase in the risks of technological disasters, it is necessary to modernize the existing environmental air monitoring systems.

One of the promising areas for the development of remote monitoring systems is associated with the use of aviation-based systems based on UAS [20-21].

To solve this problem, a system is proposed for environmental monitoring of air pollution using small-sized UAS (Fig. 6) of helicopter or aircraft types equipped with attachments controlled from a ground control station.

a



b

Fig. 6. UAS: helicopter *a* and aircraft *b* type

The disadvantage of the currently existing monitoring systems is the impossibility of determining the level of pollution at different heights from the source, the limited data, the insufficient number of measurement points to determine dangerous concentration fields and obtaining information about pollution levels, the low response speed of ground systems in an emergency.

The proposed monitoring complex can fulfill the tasks of environmental monitoring in the areas where the energy complex enterprises are located, detect violations of the sanitary protection zone and land allotment by industrial enterprises. The complex includes unmanned aerial vehicles with a payload in the form of built-in devices including gas-analyzing devices, a dosimeter, a thermal imager, etc. The complex can perform all flight tasks in automatic and semi-automatic modes using wireless data transmission systems. This product is the most attractive and differs from analogues in that the maximum possible equipment for express assessment of air pollution and other related tasks is collected in one system.

The proposed monitoring complex for the state of atmospheric air pollution based on the UAS of helicopter and aircraft types can be used to solve educational, research and applied problems.

The complex provides remote air monitoring at an altitude of 50 m to 1 km with the determination of the concentrations of O_2, CO, CO_2, NO, NO_2, SO_2, CH_2O, and the measurement of temperature, pressure and humidity in the selection zone. The relationship between the UAS and the ground station is carried out at a distance of up to 20 km (associated with radio visibility between them).

The proposed complex remains operational under the following external conditions:

- ambient temperature: -20 °C ... + 35 °C;
- illumination: not less than 4 lux;
- wind speed: no more than 10 m/s;
- intensity of precipitation (rain, snow): no more than 2 mm/hour.

The priority task of the proposed monitoring complex is determining the current concentration of pollutants in the air on several horizontal planes in the range 0...1000 m with increments of 50-100 m. On these planes along a predetermined path (for example, along the Archimedes spiral), a large number of measurements are carried out, the use of which allows to create 3D models of the transport of pollutants from the source and effectively establish pollution zones at different distances from the source. This will also help to identify the localization of pollutants (caused by temperature inversion), which can lead to the formation of smog.

The maximum distance of the UAS flight from the source of pollution ensures the detection of all possible zones of pollution accumulation from the source under study and allows to determine its contribution to the background level of pollution outside the sanitary protection zone.

8. Conclusions

1. The analysis of the composition of harmful emissions from the facilities of municipal and industrial power systems operating on solid, liquid and gaseous fuels has been carried out. It has been established that the composition of the fuel combustion products includes such substances as CO, CO_2, NO_x, SO_x, which create the greatest influence on living organisms of the biosphere. These substances are gaseous and well detected by conventional gas analyzing devices.
2. It is established that the methods for predicting the spread of pollutants in air lie in the development of the theory of atmospheric diffusion based on a mathematical description of the process using the equation of turbulent diffusion. These approaches do not take into account a large number of external factors affecting the distribution of substances in the air (the presence of large-sized objects, the effect of solar radiation, the topography, the presence and intensity of precipitation, etc.). In addition, they are used to calculate the concentration of harmful substances within the surface layer, and cannot be used to determine the level of pollution in various layers of the atmosphere.
3. The features of the functioning of automated air pollution control systems are investigated, their tasks are considered. Visualized the dissemination of these systems in the world. It is shown that some countries in Eastern Europe and Central Asia are not provided with automated air pollution control systems that can operate within the framework of world standards for informing the population about the current state of environmental air pollution in various regions of the country (in particular, Ukraine).
4. A monitoring complex for the state of environmental air pollution, operating on the basis of unmanned aerial systems, is proposed. A list of measured environmental parameters has been developed for remote monitoring of environmental air quality within communal and industrial heat power facilities. The use of the proposed monitoring complex allows to expand the boundaries of environmental monitoring, since unmanned aerial systems can provide monitoring of the air environment with high accuracy by direct methods for determining the concentrations of pollutants.

References

[1] Brandt J. Landscape practice and key concepts for landscape sustainability / J. Brandt, A.A. Christensen, S.R. Svenningsen, E. Holmes // Landscape Ecology. – 2013. – Vol. 28. – Issue 6. – P. 1125-1137. doi: 10.1007/s10980-012-9777-5

[2] Jackson S.T. Community ecology in a changing environment: Perspectives from the Quaternary // PNAS. – 2015. – Vol. 112. – Issue 16. – P. 4915-4921. doi: 10.1073/pnas.1403664111

[3] Chernyak O. Energy Perspective 2030 for Ukraine in the Context of the EU Integration / O. Chernyak, G. Kharlamova, A. Stavytskyy // Emerging Issues in the Global Economy. Springer Proceedings in Business and Economics, – 2018. – P. 113-129. doi: 10.1007/978-3-319-71876-7_10

[4] Strelkova H. Prerequisites for Regulatory Innovations in Ukraine under Renewable Energy Sector Development / H. Strelkova, A. Ghaderi, M. Strelkov, O. Ishchenko // 2019 IEEE 6th International Conference on Energy Smart Systems (ESS). – 2019. doi: 10.1109/ESS.2019.8764169

[5] Babak S.V. Monitoring of NPP environment using video surveillance and exposure dose measurement systems on the basis of unmanned aerial complex / S. V. Babak // Information Processing Systems. – 2015. – Vol 132. – Issue 7. – P. 190-194

[6] Semenenko I. Energy security of Ukraine in the context of its sustainable development / I. Semenenko // Equilibrium. – 2016. – Issue 3. – P. 537-555.

[7] Artemchuk V.O. Models of representation and data transformation in the problems of environmental monitoring in urbanized areas / V.O. Artemchuk, I.P. Kameneva, A.V. Iatsyshyn // Elektron. Model. – 2018. – Vol. 38. – Issue 2. – P. 49-66. doi: 10.15407/emodel.38.02.049

[8] Artemchuk, V.O. and al. (2017). Theoretical and applied bases of economic, ecological and technological functioning of energy objects. Kyiv, Ukraine: TOV «Nash format».

[9] Popov O. Conceptual Approaches for Development of Informational and Analytical Expert System for Assessing the NPP impact on the Environment / O. Popov, A. Iatsyshyn, V. Kovach, V. Artemchuk, D. Taraduda, V. Sobyna, D. Sokolov, M. Dement, T. Yatsyshyn // Nuclear and Radiation Safety. – 2018. – Vol. 79. – Issue 3. – P. 56-65.

[10] Babak V.P. and al. (2018). Information Provision of Diagnostic Systems for Energy Facilities. Kyiv, Ukraine: Akademperiodyka

[11] Zaporozhets A. Analysis of Control System of Fuel Combustion in Boilers with Oxygen Sensor / A. Zaporozhets // Periodica Polytechnica Mechanical Engineering. – 2019. – Vol. 63. – Issue 4. doi: 10.3311/PPme.12572

[12] Zaporozhets A. Development of Software for Fuel Combustion Control System Based on Frequency Regulator // CEUR Workshop Proceedings. – 2019. – Vol. 2387. – P. 223-230

[13] Jerrett M. The death toll from air-pollution sources / M. Jerrett // Nature. – 2015. – Vol. 525. – P. 330-331.

[14] Santigo J.L. Evaluation of a CFD-based approach to estimate pollutant distribution within a real urban canopy by means of passive samples / J.L. Santigo, R. Borge, F. Martin, D. de la Paz, A. Martilli, J. Lumbreras, B. Sanchez // Science of The Total Environment. – 2017. – Vol. 576. – P. 46-58. doi: 10.1016/j.scitotenv.2016.09.234

[15] Mehmood K. Spatial and temporal distributions of air pollutant emissions from open crop straw and biomass burnings in China from 2002 to 2016 / K. Mehmood, S. Chang, S. Yu, L. Wang, P. Li, Z. Li, W. Liu, D. Rosenfeld // Environmental Chemistry Letters. – 2018. – Vol. 16. – Issue 1. – P. 301-309. doi: 10.1007/s10311-017-0675-6

[16] Zaporozhets A. Methods and Hardware for Diagnosing Thermal Power Equipment Based on Smart Grid Technology / A. Zaporozhets, V. Eremenko, R. Serhiienko, S. Ivanov // Advances in Intelligent Systems and Computing III. – 2019. – Vol. 871. – P. 476-489. doi: 10.1007/978-3-030-01069-0_34

[17] Zaporozhets A.A. Development of an Intelligent System for Diagnosing the Technical Condition of the Heat Power Equipment / 2018 IEEE 13th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT). – 2018. doi: 10.1109/STC-CSIT.2018.8526742

[18] Yang Y. Arms: A Fine-Grained 3D AQI Realtime monitoring System by UAV / Y. Yang, Z. Zheng, K. Bian, Y. Jiang, L. Song, Z. Han // GLOBECOM – 2017 – 2017 IEEE Global Communications Conference. – 2017. doi: 10.1109/GLOCOM.2017.8253968

[19] Zaporozhets A. O. Analysis of means for monitoring air pollution in the environment / A.O. Zaporozhets // Science-based technologies. – 2017. – Vol. 35. – Issue 3. – P. 242-252. doi: 10.18372/2310-5461.35.11844

[20] Prosvirin D.A. Improvement of “Aircraft-Automatic Flight Control System” Control Loop Quality / D.A. Prosvirin, V.P. Kharchenko // Electronics and control systems. – 2016. – Issue 1. – P. 22-28. doi: 10.18372/1990-5548.47.10265

[21] Xiaojun C. IOT-based air pollution monitoring and forecasting system / C. Xiaojun, L. Xianpeng, X. Peng // 2015 International Conference on Computer and Computational Sciences (ICCCS). – 2015. doi: 10.1109/ICCACS.2015.7361361.

В.М. Ісаєнко[1], А.О. Запорожець[2], К.О. Бабікова[1], Д.В. Гулевець[1], С.А. Савченко[1]

Огляд методів та засобів моніторингу забруднення повітря

[1,3,4,5]Національний авіаційний університет, просп. Любомира Гузара 1, Київ, Україна, 03058
[2]Інститут технічної теплофізики НАН України, вул. Марії Капніст (Желябова), 2а, Київ, Україна, 03057
E-mails: [1]volodymyr.isaienko@gmail.com;[2] a.o.zaporozhets@nas.gov.ua;[3]babikova.kateryna@gmail.com; [4]gulevets@gmail.com;[5]serj6670@gmail.com

У статті проведено аналіз сучасного стану методів та засобів моніторингу забруднення повітря в Україні. Розглянуто питання утворення забруднюючих речовин при спалюванні різних видів палив (газоподібних, рідких, твердих) на великих енергетичних установках. Приведені дані відносно найбільших джерел забруднення повітря в Україні. Відображені головні недоліки моделі розповсюдження забруднюючих речовин в повітрі, що використовується як базисна. Досліджено сучасний стан систем моніторингу забруднення повітря, як в Україні, так і в інших країнах. Запропоновано вдосконалення існуючої системи моніторингу забруднення повітря на базі безпілотних літальних апаратів.

Ключові слова: забруднення повітря; моніторинг; контроль; AQI; безпілотні літальні апарати; теплоенергетика

В.М. Исаенко[1], А.А. Запорожець[2], К.А. Бабикова[1], Д.В. Гулевець[1], С.А. Савченко[1]

Обзор методов и средств мониторинга загрязнения воздуха

[1,3,4,5]Национальный авиационный университет, просп. Любомира Гузара 1, Киев, Украина, 03058
[2]Институт технической теплофизики НАН Украины, ул. Марии Капнист (Желябова), 2а, Киев, Украина, 03057
E-mails: [1]volodymyr.isaienko@gmail.com;[2] a.o.zaporozhets@nas.gov.ua;[3]babikova.kateryna@gmail.com; [4]gulevets@gmail.com;[5]serj6670@gmail.com.

В статье проведен анализ современного состояния методов и средств мониторинга загрязнения воздуха в Украине. Рассмотрены вопросы образования загрязняющих веществ при сжигании различных видов топлива (газообразных, жидких, твердых) на больших энергетических установках. Приведены данные о крупнейших источниках загрязнения воздуха в Украине. Отражены главные недостатки модели распространения загрязняющих веществ в воздухе, что используется как базовая. Исследовано современное состояние систем мониторинга загрязнения воздуха, как в Украине, так и в других странах. Предложено совершенствование существующей системы мониторинга загрязнения воздуха на базе беспилотных летательных аппаратов.

Ключевые слова: загрязнение воздуха; мониторинг; контроль; AQI; беспилотные летательные аппараты; теплоэнергетика

Volodymyr Isaenko. Doctor of Biological Sciences, Candidate of Technical Sciences (Ph.D.)
Professor at the Department of Ecology of Faculty of Environmental Safety, Engineering and Technology, Rector of National Aviation University.
Education: Kyiv Technological Institute of Food Industry (National University of Food Technologies).
Research area: air pollution, environmental safety, climate changes, biotechnology.
Publications:150.
E-mail: volodymyr.isaienko@gmail.com

Artur Zaporozhets. Candidate of Technical Sciences (Ph.D.), Senior Research Officer.
Education: Department of Applied Physics, National Aviation University.
Research area:control and instrumentation, energy audit, alternative energy, applied ecology, Consrol systems.
Publications:72.
E-mail: a.o.zaporozhets@nas.gov.ua

Katerina Babikova. Candidate of Agricultural Sciences (Ph.D.), Director of the Institute of Innovative Technologies and Leadership, National Aviation University.
Education: Institute of Environmental Safety, National Aviation University.
Research area: sustainable development, environmental safety, tourism.
Publications:30.
E-mail: babikova.kateryna@gmail

Dmytro Gulevets. Candidate of Technical Sciences (Ph.D.).
Scientific Researcher of Scientific-educational center “Ecobiosafety”, National Aviation University.
Education: Department of Logistics of National Aviation University.
Research area: environmental impact assessment, air pollution, climate changes.
Publications:35
E-mail: gulevets@gmail.com

Serhii Savchenko. Graduate student at the Department of Ecology of Faculty of Environmental Safety, Engineering and Technology.
Education: Institute of Environmental Safety, National Aviation University
Research area: environmental impact assessment, air pollution, climate changes
Publications: 20
E-mail: serj6670@gmail.com